Applications of Electric and Magnetic Fields

8.5

If you have a pet dog or cat, you probably have tags on it that give information on how to contact you if the pet ever gets lost. Unfortunately, these tags can fall off. A more secure way to identify, or ID, your pet is to have your veterinarian implant an ID microchip under the skin. The microchip stores information electronically and can be read by a scanner.

Microchips have many uses. Credit card companies and banks use them to help prevent theft of account information and fraud. Microchips are more secure than magnetic stripes, less easily damaged, and very convenient. With contactless chip cards, which are read using a magnetic field, you do not even have to swipe or insert your card; you just wave the card over the microchip reader. These advances in technology are due to our understanding of fields.

RFID Chips

Radio-frequency identification technology (RFID) is a tracking technology that uses microchips less than a millimetre in size (**Figure 1**). The microchips act as transmitters and responders (transponders) to communicate data by radio waves. This technology uses electromagnetic waves, which are a combination of electric and magnetic fields. The tag detects a specific radio signal sent by an RFID reader. When the transponder receives the radio signal, it transmits a unique numerical identification code back to the transceiver. Every tag is encoded with a unique set of numbers for the purpose of identifying and tracking items. RFID was invented in 1969 but has only recently become widely available in commercial applications. RFID tags have uses in product tracking, transportation and logistics, animal and plant identification, and payment systems.

RFID tags have many technological advantages over bar codes. RFID tags can be read inside containers and through materials such as water and body tissue. They can be embedded into any item not made of metal. They are used in wooden shipping pallets (to identify the products the pallets contain), plastic key fobs, hotel keys, credit cards, gas cards, and driver's licences. While bar codes can only be read one at a time, hundreds of RFID tags can be read simultaneously. Imagine if all the items in a store were enabled with RFID tags; when you pushed your cart through the checkout scanner, the RFID reader and tags could instantly calculate the prices of all the items in the cart (**Figure 2**).

radio-frequency identification technology (RFID) a technology that uses microchips that act as transmitters and responders to communicate data by radio waves

Figure 1 RFID chips come in all shapes and sizes, ranging from pill-shaped capsules to flat tags that can be embedded in credit cards, smart phones, clothing, and even pets.

Figure 2 A shopping cart equipped with an RFID scanner and display

Research This

Privacy Concerns Associated with RFID Technology

Skills: Researching, Analyzing, Evaluating, Communicating

SKILLS HANDBOOK A4.1

RFID technology is used in many ways that benefit society. This technology reduces costs for retailers and increases efficiency for consumers in stores by tracking individual products through unique identification codes. This same technology can be used in more controversial ways that may have a negative impact on society by allowing unauthorized, free access to personal information.

1. Research RFID technology, and choose a current product or service that uses RFID tags.
2. Describe how the tags are being used, as well as the advantages of using the RFID technology in this product or service.
3. Research RFID privacy concerns.

A. List privacy concerns associated with this product or service that are currently compromised by the RFID. Discuss possible future privacy issues that might arise with products or services if RFID tags are implemented. K/U T/I C

B. Describe steps that could be taken to reduce privacy issues. T/I C

C. How are RFID tags currently being used? K/U T/I

D. What are some privacy risks associated with RFID tags? K/U T/I

E. What actions should businesses take to ensure the privacy of personal information? K/U T/I

WEB LINK

MR Fluid Dampers

magnetorheological fluid a fluid containing suspended iron particles that, when subjected to a magnetic field, changes to a solid

Can you imagine constructing a building with a material that changes from a solid to a liquid and back to a solid again? Architects and engineers have long known that for a structure to withstand the seismic waves of an earthquake, the structure must be flexible, not rigid. **Magnetorheological fluid** (MR fluid) is a material that can change state from solid to liquid and back to solid again using a magnetic field (**Figure 3**).

Figure 3 MR fluid reacts to a magnetic field.

Although MR fluids may seem like an idea from a science fiction novel, they are now being used in the construction materials of buildings in earthquake-prone regions. Under normal conditions, an MR fluid is solid, but it changes to a liquid in response to sensors placed in strategic locations that control a magnetic field during an earthquake. This semi-liquid state of certain building components allows a building to absorb shockwaves and reduces potential damage. Buildings constructed with MR fluids are called smart structures. CAREER LINK

The liquid portion of MR fluid material is usually a type of high-viscosity (thick) oil that keeps small iron particles suspended in it. The iron particles are the key to changing the fluid into a solid and vice versa. When a magnetic field is activated near the MR fluid, the fluid greatly increases its viscosity.

Although MR fluid was introduced in the 1940s, the technology required to control the force of the magnetic field, and thus the strength of the fluid, is a recent development. Due to advancements in the technology, MR fluids are now being used in car shock absorbers, washing machines, prosthetics, and exercise equipment.

High-Voltage Power Lines

Every day, we come into contact with invisible lines of force from electric and magnetic fields. They surround any transmission or use of electricity, from high-voltage transmission and power lines to the wiring and lighting in our homes. Electromagnetic fields are also found near household appliances, electronic equipment such as cellphones, and electric motors.

In the 1980s, people began to worry that exposure to the intense electromagnetic fields around high-voltage wires posed serious health risks. Some early studies showed a link between magnetic field strength and an increased risk of cancer. People, particularly young children, living under or near large, high-voltage transformers were thought to be at high risk for developing leukemia. Since that time, however, scientists from Health Canada, the Federal-Provincial-Territorial Radiation Protection Committee (FPTRPC), and the U.S. National Institute of Environmental Health Sciences have independently reviewed over two decades of research involving adults and children exposed to electric and magnetic fields. To date, they have not found clear evidence linking high exposures with the adult cancers studied (breast cancer, brain cancer, and adult leukemia). In addition, they concluded that the studies showed only a weak association between exposure to electric and magnetic fields and childhood leukemia.

The case is not closed, however. Studies involving electromagnetic fields are difficult to perform because they are not controlled investigations. In a controlled investigation, scientists can manipulate one variable and see the outcome on a responding variable while keeping all other conditions constant. Studies related to exposure to electromagnetic fields are often correlational. A correlational study looks for relationships or patterns between measured variables and may depend on many variables affecting the outcome. Sometimes a correlation is weak but is still reported as a result. For example, a neighbourhood may have a high incidence of cancer and be located next to a high-voltage line. A result may be reported saying that high-voltage lines have been linked to cancer. However, the neighbourhood may also be located near a factory that emits a carcinogenic pollutant. The difficulty for scientists is to determine what caused the effect: was it the factory, the high-voltage lines, or both, or neither? It is always important to consider the type of study when interpreting the conclusions. WEB LINK

Medical Applications

magnetic resonance imaging (MRI) a process in which magnetic fields interact with atoms in the human body, producing images that doctors can use to diagnose injuries and diseases

Water, composed of hydrogen and oxygen atoms, is a part of all cells. The human body is approximately two-thirds water by mass and contains billions of hydrogen atoms. In a **magnetic resonance imaging (MRI)** device, magnetic fields interact with these hydrogen atoms, producing images that doctors can use to diagnose injuries and disease. The MRI uses a superconducting magnet to create a large, stable magnetic field of approximately 2.0 T. The large magnetic field is needed to produce precise images of the soft tissues inside the human body.

For an MRI machine to obtain images, a patient must lie on a movable bed that slides into a tube in the centre of the magnetic field. Hydrogen atoms in the body can behave like atomic-sized compasses whose north and south poles normally point in random, changing directions. When the body enters the magnetic field, the body's hydrogen atoms align their poles either in the direction of the field or opposite to the direction of the field. The number of atoms aligned with the field will almost equal the number aligned opposite, but there will be a small difference in the numbers (about one in a million). This difference in the number of atoms aligned versus anti-aligned depends on the particular material that the atoms are part of (such as skin, bone, or organs) and whether the material is normal and healthy or abnormal and diseased.

Next, a radio-frequency pulse is directed toward the area of the body to be examined. The pulse will cause the anti-aligned atoms to spin and align with the magnetic field. When the pulse ends, those atoms spin around again, but emit energy they absorbed from the pulse. The MRI device sends a regularly repeating radio-frequency pulse, which causes the atoms to emit a regular energy signal that can be detected by receivers.

While this is happening, three gradient magnets are activated, quickly turning on and off in a particular pattern. The gradient magnets are much smaller than the primary magnet, but they allow for precise alteration of the magnetic field. By altering the gradient magnets, the magnetic field can be specifically focused on a selected part of the body. The MRI device sends signal information to a computer, which converts the data into an image (**Figure 4**). Manipulating the gradient magnets in the MRI allows doctors to obtain three-dimensional pictures of specific body areas without moving the patient's body.

UNIT TASK **BOOKMARK**

You can apply what you have learned about applications of electric and magnetic fields to the Unit Task on page 422.

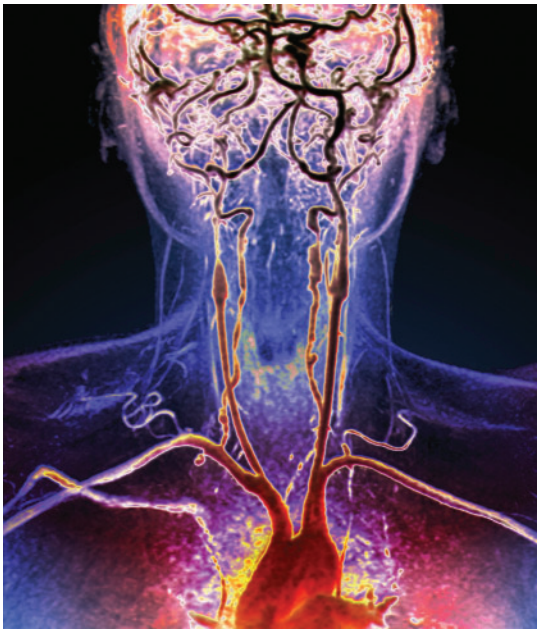

Figure 4 MRI imagery, combined with a contrast medium, has revealed aneurysm swellings in the neck and brain arteries in this 37-year-old patient. An aneurysm is a swelling caused by weakened blood vessel walls. If an aneurysm ruptures, it can cause a stroke.

8.5 Review

Summary

- Radio-frequency identification (RFID) technology is possible through the use of electromagnetic waves, which are a combination of electric and magnetic fields.
- Magnetorheological (MR) fluid is a fluid of iron particles suspended in a thick liquid that can change state from solid to liquid and back again when subjected to magnetic force.
- Current research indicates that exposure to high-voltage electric fields does not increase the risk of developing certain types of cancers, but research is ongoing.
- Magnetic resonance imaging (MRI) uses magnetic fields to produce three-dimensional images of internal body systems that provide doctors with clear and precise information about the patient's condition.

Questions

1. Describe RFID technology in your own words. K/U
2. Suppose your local grocery store uses RFID technology to keep track of all its products. T/I A
   (a) Describe the effect this technology will have on each of the following and explain your reasoning:
      (i) the number of cashiers required
      (ii) the amount of shoplifting
      (iii) the convenience for the shopper
      (iv) inventory tracking
   (b) Suppose all grocery stores started using RFID technology. List possible negative effects.
3. Highlight and analyze the major challenges ahead in the utilization of RFID technology. T/I C A
4. Explain the significance of magnetism to magnetorheological fluid. K/U
5. (a) Identify three uses for magnetorheological fluid.
   (b) Choose one of these applications, research it, and describe how the MR fluid is used in this application. K/U T/I C
6. What is a smart structure? K/U
7. Describe our current understanding of the relationship between high-voltage electric fields and human health. K/U
8. Outline the basic principle involved in magnetic resonance imaging devices. K/U
9. (a) Explain the function of magnetic fields in an MRI.
   (b) How do doctors see the differences between healthy and damaged tissue? K/U
10. An emerging technology, magnetophoresis, involves studying the motion of dispersed magnetic particles in a fluid influenced by a magnetic field (**Figure 5**). The movement of magnetic particles can be used to detect or isolate specific components in the fluid. This has implications in medicine and biotechnology. Research the various applications of magnetophoretic technology. C A

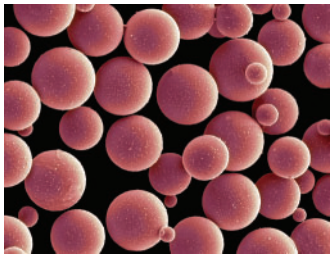

Figure 5 One application of magnetophoresis is magnetic flow sorting, where tiny magnetic balls are used to select cells.

   (a) How have they improved medical treatments?
   (b) In what ways have they advanced biotechnology?
11. Research and then write a brief article about superconductivity. What are the tools and conditions needed to achieve superconductivity? Discuss some of the many technologies made possible by the immense magnetic fields generated by superconducting wires. C A
12. Research geomagnetism and migratory animals. What species are especially sensitive to magnetic fields (**Figure 6**)? How do researchers measure this sensitivity, and how do they track the animals? Write a short report to share with the class. C A

Figure 6 The loggerhead sea turtle uses Earth's magnetic field for navigating.

WEB LINK